

**The RESIDUAL POTENTIAL
of the NORTHERN APENNINE PETROLEUM SYSTEM
A GEOCHEMICAL and STRUCTURAL STUDY of SPONTANEOUS SEEPS.**

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Introduction

The residual potential of the Northern Apennines is studied basically adopting traditional exploration methods that include the different surface and near-surface expressions of hydrocarbon leakage. We focused on the chain, that was poorly explored, due to the insufficient cover or bad acquisition of reflection seismics in the past. With this study we intend to provide new data of use for the exploration of the Apennines fold and thrust belt. Cold seeps and mud volcanoes in the Northern Apennines are aligned approximately along two belts striking northwest, located respectively near the main divide and along the foothills (Fig. 1). The Northern Apennines are a fold- and thrust belt evolved during the Tertiary as a response to the subduction of the Adriatic plate under the European lithosphere.

We studied a number of cases of spontaneous fluid emissions by coupling geochemical study on hydrocarbons, saline waters and brines with structural interpretations of the subsurface geology, aiming to fully characterize the tectono- thermal evolution of the petroleum system. Here we present three case studies to summarize some of the main results. The first one is located where the upper tectonic nappe of the chain (the Ligurian Unit) provide the main seal and overburden of the Tertiary reservoirs. The second case study pertains to the eastern sector of the Northern Apennines where the Ligurian cover does not occur. The third case study, located at the main divide of the chain, is an example of the fluid emission at the southern limit of the Ligurian nappe.

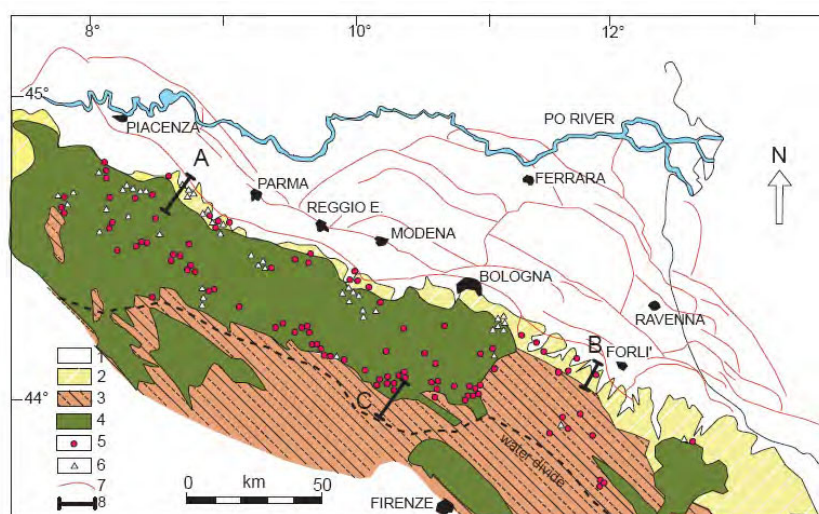


Fig. 1. Geologic sketch and locations of the fluid emissions of the Northern Apennines alongside the Po valley (modified after Borgia et al. 1986). Legend: 1- Continental Quaternary; 2- marine to continental Plio-Pleistocene foredeep units at the foothills; 3- Miocene foredeep units; 4- Ligurian-Epiligurian units; 5- spontaneous fluid emissions and 6- oil and gas from surficial drilled wells; 7- thrust front in the subsurface; 8- trace of the section: A: Salsomaggiore; B: Castrocaro; C: Porretta (modified after Capozzi and Picotti, in press).

The Salsomaggiore petroleum system

In the area of Salsomaggiore, located between Parma and Piacenza provinces in the Emilia Region (Figs 1 and 2), spontaneous fluid emissions and drilled wells are very rich in high saline water, with minor methane and oil. The chemical composition of brines shows a high content of major ions that it is quite unique amongst the known cold vents of Italy.

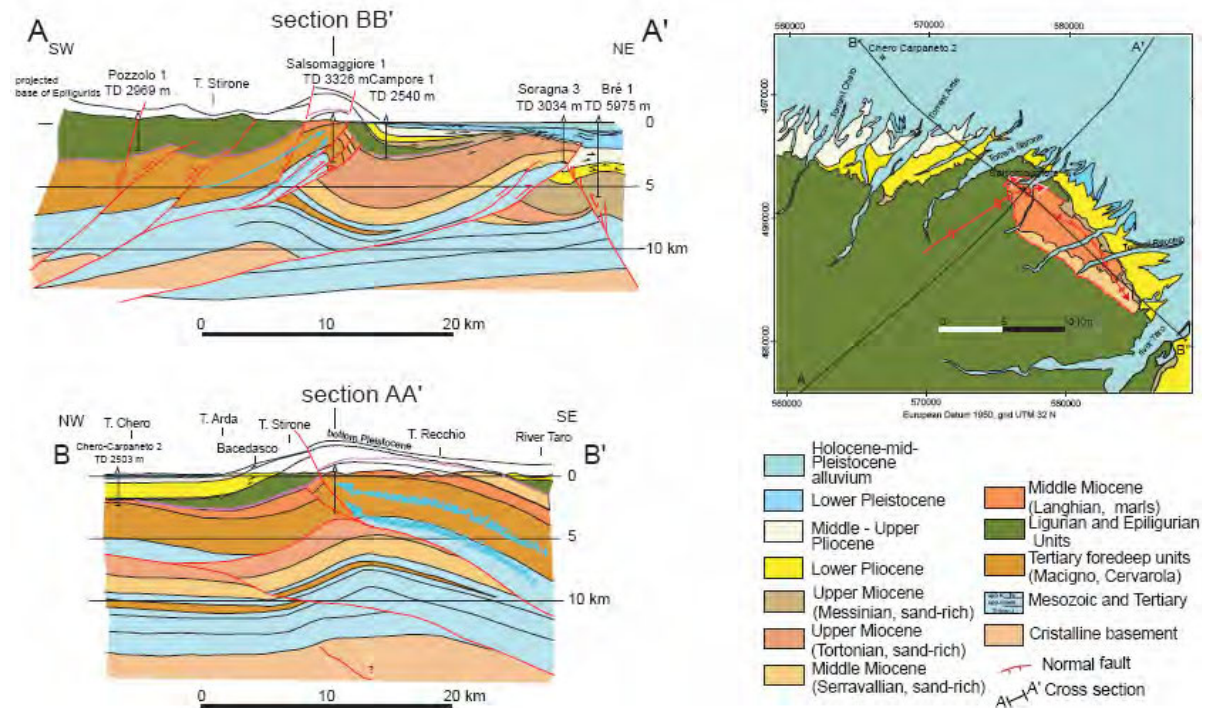


Fig. 2. Geologic sketch and cross-sections along dip and strike of the Northern Apennines foothills in the area of Salsomaggiore (see Fig. 1 for location). Modified after Picotti et al., (2007). Arrows indicate the main fluid migration pathway (after Capozzi and Picotti, in press).

The Salsomaggiore oil compositional characters were grouped by Riva et al. (1986), together with other oils of the region, including the well-known Cortemaggiore field (Pieri, 1992) (Fig. 2). The thermal maturity of the Salsomaggiore oil, with a $Ro\% > 1.1$, is higher than that of the Burdigalian reservoir (Picotti et al., 2007), documenting a migration of the oil from a deeper source. The geochemical and stable isotopes composition of the methane associated to oil in Salsomaggiore and Cortemaggiore (Mattavelli et al., 1983, see Fig. 4 and Tab. 3) is well within the field of thermogenic gas, adopting the natural gas characterization proposed by Whiticar (1994). At Salsomaggiore, a deep source of oil charged the Burdigalian reservoir during a first phase of subsidence and thrusting in the Middle Miocene. The same source charged in the Late Miocene the subsequent structure of Cortemaggiore. The Pliocene and Pleistocene remobilization of the Salsomaggiore structure produced the dismigration of the fluids toward the newly formed and eroded culmination. (Picotti et al., 2007).

The Castrocaro petroleum system

The water chemistry and the isotopic analysis of Castrocaro indicate a significant mixing with meteoric water. Notwithstanding this dilution the salinity of the water is higher than that of seawater. The gas that leaks together with the saline water in Castrocaro is composed of methane of biogenic origin. This biogenic methane occurs within deformed Upper Neogene

units, which represent an uplifted portion of the main hydrocarbon system exploited in the Eastern Po Plain.

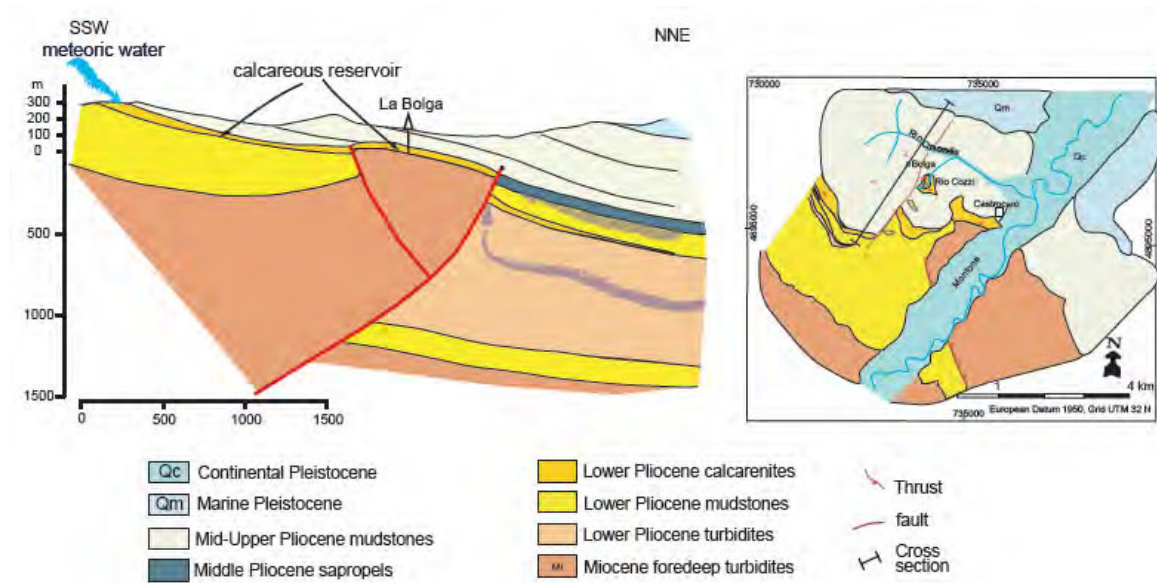


Fig. 3. Geologic sketch and cross-section along dip of the Northern Apennines foothills in the area of Castrocaro (see Fig. 1 for location). Deep interpretation after seismic lines in the subsurface of the Po Plain. Coloured arrows indicate the main fluid migration pathway (after Capozzi and Picotti, in press).

The structure of the Castrocaro field is shown in the cross section of Figure 3, where a thrust deforms the Miocene foredeep succession, allowing the Pliocene to onlap the thrust top with shallow water calcarenites. Because of the recent northeast tilting of the entire succession at the mountain front (see Picotti and Pazzaglia, 2008), Castrocaro shows a geometry of the carriers, driving connate waters and biogenic methane toward the foothills.

The Porretta petroleum system

The fluid emission along the main divide of the Northern Apennine has higher temperature than that at the foothills (average T from 21°C to 35°C). The fluids consist of low saline waters and gas. The isotopic analysis indicates that meteoric water is dominant. The Porretta fluid vent releases thermogenic methane, which likely undergoes to anaerobic methane oxidation within the reservoir. Present migration of saline waters and gas in this system is likely due to the enhanced displacement due to surface water circulation in a fractured system at depth up to 1000m.

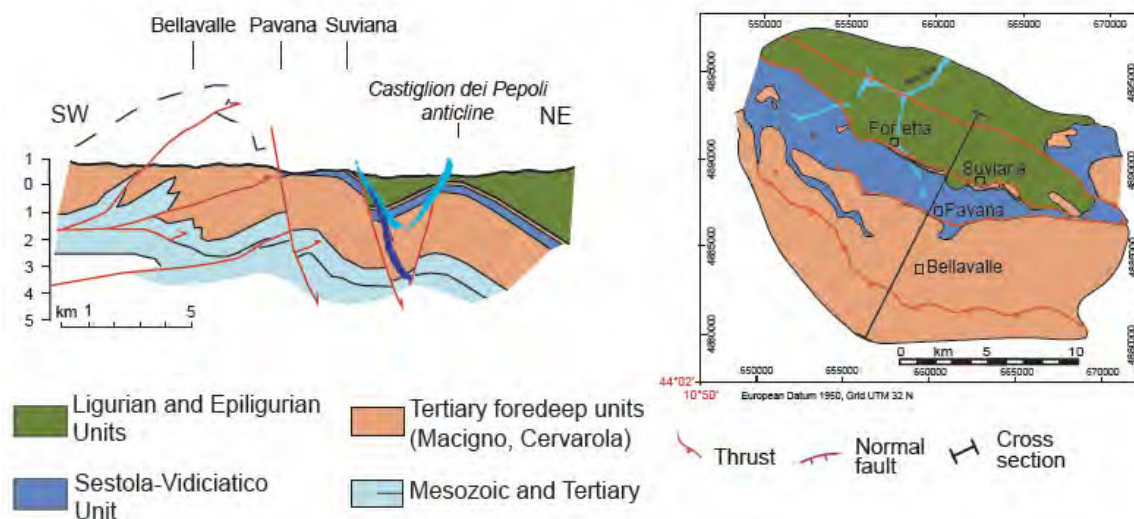


Fig. 4. Geologic sketch and cross-section along dip in the area of Porretta, near the main divide of the Northern Apennines (see Fig. 1 for location). Coloured arrows indicate the main fluid migration pathway.

At Porretta (see Fig. 1 for location), there is a sharp geological boundary between the northern hilly side, characterized by the presence of the Ligurian nappe and the southern mountainous portion, where the intensely deformed Tertiary foredeep succession crops out (Fig. 4).

Conclusions

The study, based on some cases distributed along the Northern Apennine chain, led to identify an extreme variety of the natural settings, where fluids leak out from reservoirs of different ages, which are deformed at different times and as a consequence of different stress regimes (compressional or late-orogenic extensional). A common point is the presence of good reservoirs of variable volumes, in several cases disrupted by recent deformation. These reservoirs drain hydrocarbons that leaks from deeper reservoirs or that are formed by a source that is deeply buried in the chain, but still producing. Minor biogenic gas accumulations characterize the eastern mountain front, that was more recently deformed.

References

- Capozzi R., Picotti, V., in press. Spontaneous fluid emissions in the Northern Apennines: geochemistry, structures and implications for the petroleum system. In J. Craig (ed.): *Hydrocarbons in Contractual Belts*. The Geological Society Spec. Publ., London.
- Picotti V., Capozzi R., Bertozzi G., Mosca F., Sitta A., Tornaghi M., 2007. The Miocene petroleum system of the Northern Apennines in the central Po Plain (Italy). In: Lacombe O., Lavé J., Roure F., Vergès J. (Eds): *Thrust Belts and Foreland Basins*. *Frontiers in Earth Sciences Special Volumes*, 117-131. Springer-Verlag.
- Picotti V., & Pazzaglia, F. J. 2008. A new active tectonic model for the construction of the Northern Apennines mountain front near Bologna (Italy). *Journal Geophysical Research*, **113**, B08412, doi:10.1029/2007JB005307